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QUALITY AND ITS PRESERVATION IN PROCESSED FOODS

Proceedings
Eastern Experiment Station
Collaborators' Conference
October 26-27, 1971

The Eastern Experiment Station Collaborators' Conference on Quality and its Preservation in Processed Foods, held on October 26-27, 1971, at Philadelphia, Pa., was one of a series of annual collaborators' conferences organized by the regional marketing and nutrition research divisions of the Agricultural Research Service, United States Department of Agriculture. The collaborators are staff representatives of the State agricultural experiment stations in each of the four regions. To assure depth and breadth in subject matter, a single area of important research is selected for each conference.

Views expressed in these summaries of papers presented at this conference are not necessarily those of the United States Department of Agriculture. Requests for further information must be sent to the speakers. Mention of commercial products or firms does not imply USDA recommendation or endorsement over others not mentioned.

Underscored numbers in parentheses refer to references at the end of each paper. References, figures, and tables are reproduced essentially as supplied by the author of each paper.

PROGRAM AND CONTENTS

Tuesday, October 26

Presiding: W. A. Maclinn

Wednesday, October 27

Presiding: I. A. Wolff

17 percent. With the exception of the loss of tobacco, this represents no significant change of emphasis. Likewise, the overall composition of our staff has not changed greatly. We have about 350 people located here, including temporary personnel and student trainees, and a total of about 430 employees. Of those, 225 are professional and scientific (90 Ph. D.'s).

In common with other research organizations, we remain in a period of budgetary and manpower restrictions. Nonetheless, our staff is continuing a high level of productivity with a commendable output of competent basic and applied research results. The following is just a sampling of these developments.

Selected Accomplishments

On-the-Farm Cherry Processing. In cooperation with Agricultural Engineering and Michigan State staff members, procedures were devised for orchard-side plants, which resulted in greater economy and improved quality. About 15 percent of the tart cherry crop was handled by this method last year.

Milk-Orange Juice Beverage Developed. Our scientists cooperated with Dairy Development, Inc., a union of dairy cooperatives in the Northeast, to develop a tasty, refreshing beverage that is about 57 percent milk, 38 percent orange juice, 5 percent sugar, and a small amount of emulsifier. Consumer tests suggest excellent acceptance.

New Dairy Spread. This is a spreadable product consisting of 37-1/2 percent whey solids, 37-1/2 percent milk fat, and 25 percent water. People who have tasted this nutritious food product like its flavor and texture.

New Concept of Allergens in Milk. A small fraction of the population is allergic to cow's milk, but apparently they do not give the usual skin test reactions. Our scientists showed that the gastric enzyme pepsin can act on milk proteins to produce new allergic peptide substances. This finding contributes to an understanding of food allergies.

Phosphate-Free Detergents. Alternate systems from the usual synthetic surfactant-phosphate builders approach are being explored. Looking especially promising at this time is the concept of using soap in conjunction with selected tallow derivatives called lime-soap dispersing agents. The new combinations being tested are biodegradable and show good detergency, even in hard water.

I could go on presenting results of successful research programs, but the time suggests that I stop at this point.

Staff Consultations

In the brochures at your places you will find a listing of our major program areas and our key staff members. Again, we welcome you here and urge you to make use of your free afternoons to discuss research of mutual interest with our scientists.

PRESERVATION OF ESSENTIAL AMINO ACIDS

DURING PROCESSING OF DAIRY PRODUCTS

(Abstract)

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Good nutrition demands the inclusion of sufficient essential amino acids in the diet. The proteins of milk are excellent sources of these nutrients, providing that the essential amino acids are not altered or destroyed during the manufacture of dairy products. Heating milk above the minimum requirements for pasteurization promotes the interaction of lactose with the terminal amino group of the essential amino acid lysine, thereby rendering it "unavailable" to the consumer. Additional heating will lead to the destruction of the lysine-lactose complex and decrease the total lysine in the protein that is measurable after acid hydrolysis. The significant destruction and loss of availability of lysine during the sterilization of condensed milk has been noted by a number of investigators. Also noted was lysine loss during the drying of milk on steam-heated metal drums.

Recently EMN has become concerned with measuring the loss of lysine during the drying of cheese wheys. Spray drying of whey can be carried out without significant change in its lysine content. Roller drying causes measurable reduction which relates directly to the drying temperatures used.

Interest in producing whey protein concentrates has been increasing. Study of the lysine content of materials of this type produced in our pilot plant and manufactured by industrial groups has generally shown that dried products containing high levels of intact lysine are easiest obtained when the lactose content of the product is low. Whey protein concentrates containing 80 percent protein, having 10 grams of lysine per 100 grams protein, can be produced by combining reverse osmosis with gel permeation.

In studies of lysine in dairy products, total lysine values are relatively easy to obtain by use of ion-exchange chromotography. However, there is no good method of determining the biologically "available" lysine content of foods by chemical means. Even more difficult is the quantitative analysis of the biologically "available" sulphur-containing essential amino acid methionine. Obviously, this amino acid as present in milk proteins is subject to oxidation during dairy product manufacture and the extent of this change remains largely unknown.

KNOWLEDGE OF MILK COMPOSITION AND COMPONENT PROPERTIES AS AN AID IN PROCESSING

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The Milk Properties Laboratory of the Eastern Marketing and Nutrition Division has been engaged in basic research on the physical-chemical properties of milk for over a decade. Although the nature of this research has seemingly been unrelated to practical application, the results have led to a better understanding of the factors which influence the physical stability of the milk system.

Scientists in our laboratory have regarded milk as a biological fluid which is subject to a variety of physical alterations. These alterations (coagulation, gelation, fat separation) may arise through bacterial or enzymic action, changes in the ionic equilibrium, physical manipulations, or genetic variations in the milk proteins (caseins and whey proteins). The latter area of research, genetic variations, has been particularly rewarding in answering, at least partly, why the milk of individual cows is so variable. For decades it had been tacitly assumed that, with minor variations, all milks were identical. Indeed, milks from one cow to another did not show identical heat stabilities; these differences were attributed almost exclusively to minor variations in the ratio of cations (Ca^{2+}, Mg^{2+}) to anions ($PO_4{}^{2-}$, citrate^{2-}). The discovery of genetic variants in the caseins (substitution of one amino acid for another or the deletion of several amino acids from the protein molecule) shed new light on the problem of heat coagulation of the milk system.

It has been considered likely that milks containing certain genetic variants of the α_{s1}-, β- and/or κ-casein series might be more sensitive to heat than others. This hypothesis was borne out when it was discovered that milks containing the rare casein variant α_{s1}-A (deletion of 13 amino acids from the protein molecule) were abnormally sensitive to heat; i.e., they coagulated in 3-5 minutes. The discovery of a mutant form of a "non-functional" protein in relation to a processing defect was the first of its kind, and clearly demonstrated the value of basic research with respect to a very applied problem.

A few points regarding genetic variation of milk proteins deserve some comment at this time: (1) Genetic variation is breed specific; i.e., the Holstein breed (or related breeds) show more peculiar variants than the other well-known breeds--Jersey, Guernsey, Brown Swiss, and Ayrshire. (2) Artificial insemination (i.e., the use of the semen of one bull to sire thousands of dams) may introduce an undesirable protein variant into a breed of cattle.

(3) The effects of genetic variation on the overall heat stability of milk in relation to the ratio of cations to anions is not clearly understood.

During the course of investigations on the genetic variation of milk proteins, studies were undertaken to determine the physical properties of the isolated milk protein variants. It was observed that certain variants of the proteins (in the presence of Ca^{2+}) did not hold as much water, termed water of solvation, as other variants. For example, α_{s1}-casein A was less solvated than the B or C variants. Relating this information to the milks from which the variants were isolated, we observed that the caseins in milks containing α_{s1}-A were also less solvated and, surprisingly, less heat stable! Analyses of several hundred milk samples brought us to the conclusion that, in general, if casein micelles contained less than 2.0 grams of water/gram of protein, the milk system was heat unstable. Conversely, if the caseins contained more than 2.0 grams of water/gram of protein, the system was heat stable. In practical terms, such knowledge is of value in ascertaining the processing behavior of concentrated milk products.

Lastly, we should consider the structure of casein micelles because a knowledge of this should explain the physical phenomena associated with the milk system. It is clearly known that κ-casein, the protective colloid of the casein system, prevents the precipitation of casein from suspension in the presence of Ca^{2+}. Where κ-casein is located, on the interior or the exterior of the micelle, is a question of much dispute. One school of thought contends that κ-casein is located in the center of a micelle serving as a nucleating agent for the calcium insoluble casein components, α_{s1}- and β. The second school of thought says that κ-casein is located on the periphery of a core of α_{s1}- and β-caseins and serves to keep the micelle suspended. A third school of thought bases its arguments for micelle construction on the examination of lactating mammary cells by the electron microscope. This school argues that κ-casein is distributed equally on the surface or the interior of casein micelles. The concept embraces the two earlier schools of thought, but bases its arguments on what the functional lactating cells appear to be doing--not on _in vitro_ studies. Evidently, following biosynthesis on the ribosomes, the newly formed polypeptide backbone of the caseins enters the Golgi apparatus where phosphorylation and carbohydration, as well as assemblage into casein micelles, occurs. The process of assemblage occurs in stages: (1) Long strands of casein polymers--held together by calcium-phosphate linkages--form. (2) These strands coil up into micelle-like structure, maturing as the Golgi vacuoles approach the plasma membrane for secretion. (3) The Golgi vacuoles become contiguous with the plasma membrane and release their contents into the alveolar lumen.

Understanding the basic construction of a casein micelle is particularly advantageous when attempting to ascertain the reasons for gelation and coagulation of milk. For example, the fact that rennet coagulation cannot occur without κ-casein suggests that it must be located on or near the periphery of the micelles. This concept does not preclude, however, that it is not also located in the interior of the micelle itself.

MAINTENANCE OF QUALITY IN POULTRY MEAT

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Many of the qualities characterizing commercial poultry products of today are built into the product after the live bird arrives at the processing plant. The bird furnishes all of the precursors--highly nutritious, well-balanced protein and several vitamins; a muscle fiber structure capable of imparting chewiness, tenderness, juiciness, and cohesiveness; and a mixture of amino acids, sugars, nucleotides, and lipids that react with heat to produce the very desirable cooked poultry flavor.

However, it is the responsibility of the food industry to develop and retain the important food qualities. The following major quality areas will be discussed in this paper, with emphasis on the fundamental bases for present status and possible future developments: (1) Wholesomeness (low levels of bacterial contamination and freedom from pathogens and toxicants, (2) texture (tenderness, juiciness, and cohesiveness), (3) flavor, and (4) stability of all desirable qualities throughout processing, storage, and marketing. Four other qualities of major importance are price, convenience, appearance, and nutritional value. These will not be discussed, except to state that the nutritional value (high content of protein very high in biological value; low content of fat that is reasonably unsaturated compared to other animal fats; substantial amounts of niacin, folacin, riboflavin, phosphorus, and iron) is remarkably constant and stable in commercial poultry products. No important losses take place in the processing, freezing, or frozen storage of the raw product; and essentially the same can be said for dehydration and ambient storage of the dehydrated product. Cooking causes 10 to 30 percent losses in niacin and riboflavin, around 30 percent loss in folacin, and under the conditions reported, 35-50 percent loss in tryptophan.

Wholesomeness

Modern technology relies on sanitation and low temperature for the control of spoilage bacteria and pathogens. In addition, cooking poultry products is a safeguard that contributes to their wholesomeness at the point of consumption. Pathogens such as salmonellae represent a potential hazard in the temperature range of 120°-40° F., while the psychrophilic spoilage organisms such as <u>Pseudomonas</u> and <u>Achromobacter</u> have appreciable and important growth rates down to 30° F. and below. Marked increases in chilled shelf life have been accomplished by reducing transportation and storage temperatures from 35°-37° to about 28° F., where the product is firm but not completely frozen. Proper storage (0° F. and below) and thawing procedures for frozen poultry products eliminate bacteriological hazards. Because of the recent trend of marketing precooked products, current efforts focus on the elimination of cross contamination from contaminated raw products to already cooked products, either in a further processing plant, the home, or an institutional kitchen.

Surface pasteurization of poultry in order to attain the same degree of safety that we demand in our dairy and egg products is theoretically feasible but not presently technically developed. For example, it has been demonstrated that exposure of inner and outer surfaces of ready-to-cook chicken fryers to subatmospheric pressure steam at 160° F. for 4 minutes can provide a 5,000-fold reduction in total aerobic bacterial count. If highly sanitary processing practices are used to reduce initial counts by 10- to 100-fold, a pasteurization step can reduce the final count at the point of packaging down to negligible levels. Such a pasteurization step using steam denatures (cooks) the superficial layers of the skin and flesh, changing their appearance, but does not otherwise affect the quality of the poultry.

Tank-immersion scalding has frequently been indicted for bacterial contamination and cross contamination of poultry carcasses. A more sanitary alternative, which has been established on a small-batch basis but has not been developed to a continuous commercial process, is scalding by subatmospheric steam at relatively high vacuum and low temperature, ranging from 124° F. up. Subatmospheric steam scalding results in an almost dry, easily picked bird with no skin abrasion. A reduction in liquid waste and a substantial reduction or elimination of air sac contamination is accomplished.

Texture

Tenderness and related qualities that are dependent on the final stage of the muscle fibrillar structure are easily influenced by changes in processing practices, such as feather removal, chilling (aging), and cutting-up. In the first two to three hours after slaughter, stimulation of the muscle fibers and resulting irreversible toughening are produced by excessive heat, as in scalding or precooking, or by mechanical actions such as heating by mechanical feather pickers or cutting the carcass into parts across the muscle. The severity of these effects is illustrated by a 50-percent shortening of excised prerigor muscles induced by electrical stimulation, freeze-thawing, or heating. The fundamental bases for all textural qualities and changes in them must be sought in the ultimate structure of the muscle fiber system, and a completely verified picture of the mechanism of muscle tenderization (or toughening) is not yet available to us. There is evidence that normal tenderization in the first 24 hours after slaughter involves breakage of actin (I) filaments adjacent to the Z line. However, more sites in the sarcomere structure may conceivably be involved, since the development of rigor or inextensibility is considered to be caused by the locking of actin and myosin filaments at fixed positions quite removed from the Z lines of the sarcomeres.

Recent commercial processing trends toward hot cutting of fryers immediately after evisceration, or cutting up and cooking shortly after plant spin-chilling, has refocused attention on possible effects on tenderness.

Some workers have found that hot-cutting does not produce toughening, while others have found 30-percent increases in toughness under commercial conditions and as much as 100-percent increases under laboratory conditions. For either chilled-cut or hot-cut, wide differences in general levels of tenderness have been noted between birds processed in the laboratory and in the commercial plant. These differences suggest that commercial slaughtering and defeathering practices, other than hot-cutting, may be imposing a general, perhaps undesirable, level of toughness in commercial birds.

Other important aspects of textural quality that must be maintained are juiciness and water-holding capacity (particularly important in precooked and other further processed products) and cohesiveness. The quality of cohesiveness basically involves the connective tissue (collagen) binding the fibers and fiber bundles together; old fowl may be too cohesive, while some processed products, such as freeze-dried or irradiated poultry, may have too little cohesiveness, resulting in an undesirable cottony or mushy texture.

Flavor

With few exceptions, potential optimum poultry flavor is established by the species-specific composition of poultry muscle, and is little affected by variations in production practices or processing technology. The major precursors of cooked poultry flavor probably reside in the sarcoplasmic, water-soluble fraction of the muscle, although the myofibrillar proteins may furnish some amino acid reactants; the fat may also contribute as a modifier and solvent-carrier of flavor. Salts, glutamic acid, and nucleotide breakdown products have been implicated in cooked poultry taste. Many compounds, such as organic sulfides and amines, have been definitely or tentatively linked to cooked poultry aroma. Many other compounds--including aldehydes and ketones either produced as amino acid, amino acid-sugar, or fatty acid degradation and reaction products--have also been identified and suggested to be contributors to flavor. Strecker degradation products of amino acids have likewise been implicated.

Stability

Storage life is determined by storage temperature, initial bacterial level in the case of chilled products, moisture content, fat content and composition, additives such as antioxidants, packaging and within-package environment, extent of cutting-up and comminution, and cooking (i.e., whether raw or precooked and method of cooking used). Present storage problems exist mainly in precooked and highly formulated products in which warmed-over flavor and rancidity can develop. Some techniques for extending shelf life, such as nitrogen packing, have been adequately demonstrated but still await commercial application.

In the United States, maintenance of quality in poultry products is presently at a high technical level. Technical breakthroughs which, if achieved, might add further to quality are: an economical, technically feasible procedure for the surface pasteurization of poultry; a quantitative description of the minimum essential components needed to produce cooked poultry flavor; and the stablishment of chemical and physical events that are critical in the development and resolution of rigor in poultry muscle.

FUNCTIONS OF NITRATES AND NITRITES IN CURED MEATS

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More than 8 billion pounds of cured meat, such as ham, bacon, frankfurters, and other sausage products, are produced annually. Curing can be described as the diffusion of the curing agents throughout the meat to produce physical, chemical, and bacteriological changes that give the meat extended shelf life or stability, stable permanent color, and modified texture and flavor.

Preservation

Cured meat products have enjoyed a long period of safe consumption due to their stability. This stability is a result of the inhibitory activity of the curing salts on bacteria that cause spoilage and food poisoning, particularly on the toxigenic *Clostridium botulinum* whose growth can occur under anaerobic conditions in vacuum-packaged and canned products.

In this respect, the data shown in figure 1 by Pivnick *et al*. (14) is of considerable interest. The delay in toxigenicity and spoilage of vacuum-packaged ham is related to the concentration of nitrite. At the 100 parts per million (p.p.m.) level of sodium nitrite concentration, it took 4 days for the samples to become toxic, and at the 200 p.p.m. level, 8 days were required. With the exception of those containing 300 p.p.m. of sodium nitrite, the samples became toxic before they were sufficiently putrid and spoiled to be considered inedible. Therefore, it is important to understand the role of the curing agents in the microbiology of meat. The inhibition of bacterial spoilage in cured meat products is dependent not only on the interrelationship of the curing agents, but also on the number of bacterial spores present, the degree of thermal processing, the pH of the preparation, and the temperature of storage.

Duncan and Foster (6) report that the commercially used concentration of 150 p.p.m. of sodium nitrite does not prevent spores from growing in meat; however, it does delay spoilage. Bulman and Ayres (3) indicate that 400 to 800 p.p.m. is required to have a preservative effect. Why, then, do low levels of sodium nitrite show inhibitory activity? The reason for this is in part due to the use of nitrite in combination with sodium chloride (13).

Insofar as nitrite is used as a preservative agent, lower levels of it appear to be safe. Spencer (17) states that raw meat contains approximately 1 Clostridal spore per gram. Pivnick et al. (13) indicate that greater than 15 p.p.m. sodium nitrite would provide satisfactory protection against this level of spores. However, Silliker et al. (16) recommend that a minimum of 78 p.p.m. sodium nitrite is required to produce a stable product.

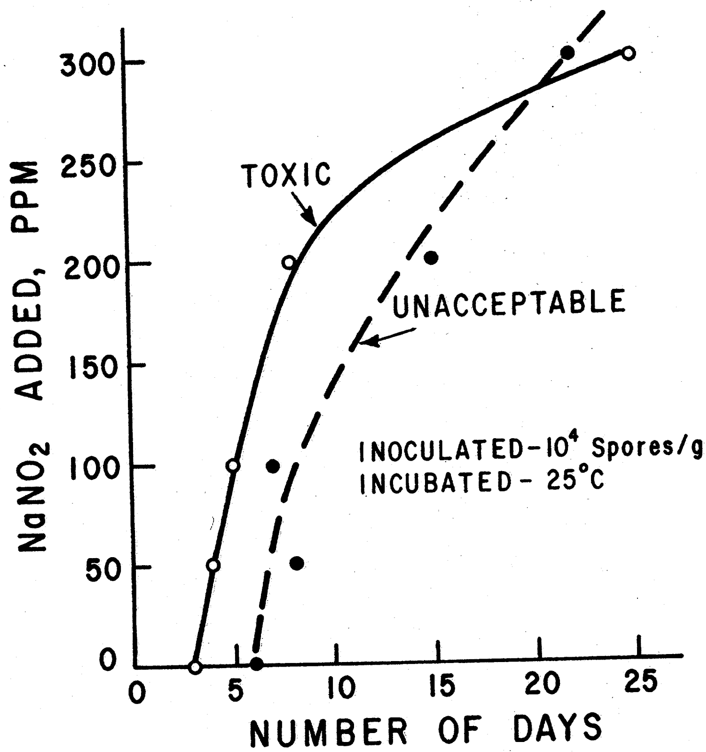

Figure 1.--Effect of sodium nitrite on toxigenicity and acceptability of cooked sliced ham inoculated with C. botulinum.

Is the active ingredient sodium nitrite per se or some compound derived from it? The antibacterial activity of nitrite depends upon the pH. Shank et al. (15) report that the bacteriostatic action of nitrite occurs in the pH range of 4 to 6, with the greatest activity at pH 4.5 to 5.5 (the average pH of meat is 5.6). Nitrite is known to undergo the transformations shown in figure 2 (15). The presence of nitrous acid, which is the compound mainly responsible for the antibacterial activity, is prolonged at pH 4.5 to 5.5. Nitric oxide, sodium nitrite, and sodium nitrate have no effect on bacteria. Other authors (3, 6) have come to the same conclusion with regard to the role of nitrate. In fact, Silliker et al. (16) states that nitrate actually stimulates aerobic spoilage by supplying a source of oxygen.

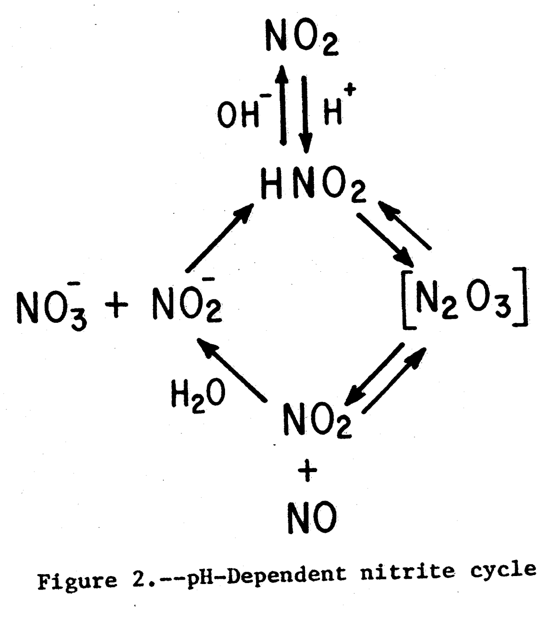

Figure 2.--pH-Dependent nitrite cycle.

What is the role of nitrate in curing? It appears to have no direct role. The use of nitrate may be traditional, originating from the period when longer pickling and processing times were used prior to cooking, thus allowing the nitrate to be reduced to nitrite by bacteria. During short curing this reduction is so small that it is difficult to develop cured color in meats (19). Also most of the nitrate-reducing bacteria in meats are killed by cooking for 50 minutes at 63° C. (145° F.), which is comparable to conditions used in commercial practice. This would help prevent the formation of nitrite from nitrate after heat treatment. A survey of the literature, together with some of the data presented, suggests that for short-cure processing the level of nitrate can be reduced from approximately 1,700 p.p.m., presently allowable, or it can even be eliminated from certain products.

Color

The most important objective in curing meats can be considered the development of an attractive and desirable color. Figure 3, taken from an American Meat Institute Foundation publication (21), shows that the stable red or pink color of cured meat is a result of the reaction of nitric oxide with red muscle pigment, myoglobin, producing nitrosomyoglobin which upon heating develops the pink nitrosohemochrome pigment. Cured meat is distinguished from uncured meat in the stability and maintenance of the same color after cooking. The amount of nitrite is critical to maintaining the color; insufficient nitrite reserves result in fading upon storage, while too much nitrite will cause green-brown products to form, a condition usually known as "nitrite burn."

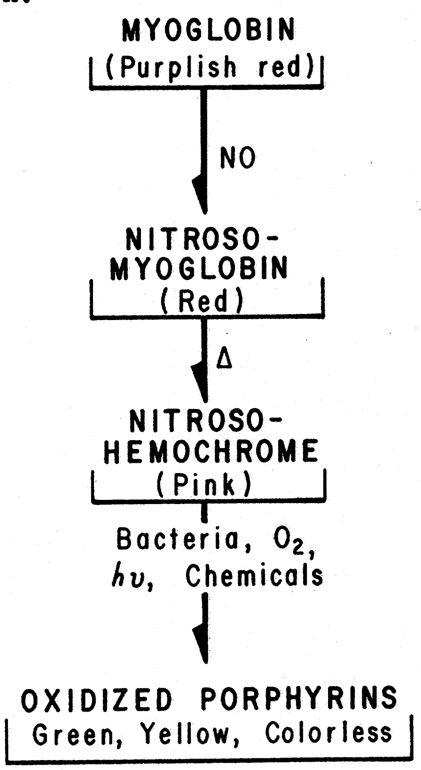

Figure 3.--Color changes in meat during curing.

Möhler (11) reports that as little as 10 p.p.m. sodium nitrite is needed for the production of color. However, larger amounts may be needed in different types of cured meat products to prevent fading. Takagi *et al*. (18) has recommended using 100 p.p.m. sodium nitrite for cured meats which are cooked immediately to provide satisfactory color and protection against fading.

Flavor

The contribution of curing to flavor is the area where the least research has been done, but potentially this is the most important. Brooks *et al*. (2) in 1940 reported that the flavor of cured bacon and ham is primarily due to the action of sodium nitrite. Similar results were found by other workers (4, 20).

The constituents responsible for cured flavor and their precursors are still unknown. Additional work in this area is necessary since a substitute for nitrite may be possible only if the "cured" flavors can be added artificially.

Barnett et al. (1) indicate a minimum of 0.1 gram per liter (g./L.) sodium nitrite as satisfactory for developing the flavor of cured ham compared with a normal pickle containing 1.5 g./L. Little else has been published on this subject.

Potential Hazards

The use of sodium nitrite is not without potential hazards. Occasionally there are incidents of accidental poisoning resulting from the consumption of meat products where excessive amounts of nitrite were used (12). The resulting condition is called methemoglobinemia, where part of the hemoglobin is oxidized by nitrite to methemoglobin with a subsequent reduction in the oxygen binding and transporting power of the blood.

There is another potential hazard, that of nitrosamine formation. Nitrosamines are normally formed when secondary amines and their precursors react with nitrite under acidic conditions. Since the carcinogenicity of dimethylnitrosamine was discovered in 1956 (10), other nitrosamines have been shown to have carcinogenic activity in test animals (5). Although to date the presence of dimethylnitrosamine has been confirmed in only a small number of food products in extremely low quantities (7, 8, 9), the possibility of nitrosamine formation during the curing of meats is of concern. Limiting or decreasing the amount of nitrate and nitrite used in cured products would help eliminate the potential hazards.

While, according to the literature, it is possible that the level of sodium nitrite may be safely reduced from the presently allowable 150 p.p.m. to 75 p.p.m., it would be very difficult to replace it completely on the basis of our current knowledge. Sodium nitrite is relatively inexpensive; it has a broad range of antimicrobial activity over the pH range of meat; it forms nitric oxide to give an attractive, stable, non-toxic coordination compound with the meat pigment; and, more importantly, it modifies the flavor of raw meat components. Therefore, it appears that the use of sodium nitrite will be with us for some time.

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EMN FRUIT AND VEGETABLE RESEARCH RELATED TO PROCESSING QUALITY

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Our research program on fruits and potatoes includes several projects so related to processing quality that I can include them in my discussion today. We are concerned with either maintaining it, measuring it, or predicting it. I will describe examples of each; I will also describe the viewpoint of our Engineering and Development Laboratory in relation to research on processing quality of fruits and vegetables.

First, I will describe part of our research on the mechanical harvesting of fruits such as tart cherries, sweet cherries, and grapes.

Tart Cherries

Tart cherries are probably the fruit most completely harvested by machine. The reasons for this are not hard to find--the relative cost of hand harvesting is very high, the supply of farm labor is decreasing, and nearly 100 percent of the fruit is destined for processing. One of our researchers, Dr. Robert Whittenberger, has been concerned with the effects of machine harvesting on processing quality of fruit. He has been our representative on the joint mechanical harvesting team with members of the Agricultural Engineering Research Division and the Horticulture Department of the Michigan State University. During the 13 years of this collaboration, tart cherries in Michigan have become almost completely machine harvested. Dr. Whittenberger's general responsibility has been to determine, preserve, and improve processing quality of the fruit. Evaluation of processing quality on tart cherries was largely done by estimating the degree of bruising and scald, and the pack-out yield and grade. Modifications in harvesting practices were evaluated by following commercial-sized lots through the processing plants and determining USDA grade of the processed products. Processing steps were individually studied in the plants to determine where excessive bruising occurred.

In general, when the bruising from mechanical harvesting was added to that encountered in the processing plant, the result was reduced quality and poor yield. Thus, to make high-quality products from mechanically harvested cherries, a reexamination of the entire layout of the individual plants was necessary. Operations causing needless further bruising to the fruit were ascertained, and subsequently changes were made in the procedures as indicated. Studies of product quality in terms of bruising were also made of individual harvesting and unloading operations. It was found that individual harvesting equipment operators produced cherries varying fourfold in the harvest bruise they caused and tenfold in subsequent scald. Unloading at the processing plant doubled the incidence of scald.

One response to this problem has been the elimination of the rehandling and consequent bruising associated with weighing the cherries. A new volumetric procedure using calibrated hauling tanks and a device to determine level has been introduced and is now accepted by the State Department of Weights and Measures. Over half of the crop changed hands this way in 1971. This was preceded by careful measurements of the effects of various factors on the bulk density of tart cherries in water.

Even so, the large processing plants of past years have had difficulty in achieving a quality product. Excessive delays in hauling, difficulties in scheduling, and lack of adequate cooling contribute to deterioration. This provided a situation where smaller, grower-owned processing plants in the orchard could greatly decrease the overall time between soak tank and final product to achieve a high-quality product. This is now taking place, and eight such small processing plants, using local labor and rented equipment, were operated in 1970 and ten in 1971. Recommendations of the joint mechanical harvesting team were followed, and all achieved high quality in their products and an increased return to the growers.

Sweet Cherries

The availability of harvesting machines for tart cherries in Michigan made their evaluation for sweet-cherry harvesting inevitable. Michigan produces about 80 percent of the Eastern sweet cherry crop, which is in turn about 25 percent of the National crop. However, about 90 percent of Eastern production is processed, while only half of the Western crop is. Use of shakers requires evaluation of bulk-handling methods to minimize the effects of harvest damage on the processing quality of the fruit. Sweet-cherry processing in Michigan is about 90 percent to maraschino cherries. Earlier work in Michigan and elsewhere had indicated that early brining minimized discoloration from bruising. Studies were therefore undertaken in the field to verify this, using controlled bruising of cherries and imposing various delays before brining. The parameters measured as indicators of processing quality before and after brining were cherry weight, diameter, firmness, stem attachment force, and general product quality as evaluated by a panel of five experts.

The conclusions, without going into details, were that brining immediately after harvest produced a markedly superior product from mechanically harvested fruit, though at a 1 percent sacrifice in product yield. This led the team to recommend brining in the orchard and hauling in brine. There has been resistance to adopting this practice, but now that buying tart cherries by volume is becoming accepted, we should see an increasing trend to orchard brining of sweet cherries. The quality of machine-harvested sweet cherries is also reduced by the relatively greater difficulty of shaking the fruit off, as sweet cherry trees are larger, and the fruit is usually removed before true maturity is reached. This results in excessive bruising. Experimental use of Ethrel (2-chloroethylphosphonic acid*), an abscission agent, has improved this situation and increased yields for those varieties with relatively large attachment forces. For example, on one large-scale test, application of 500 p.p.m. Ethrel increased fruit recovery for the Emperor Francis variety from 76 to 92 percent, and for Windsor from 70 to 88 percent. Furthermore, bruise damage was reduced, as was the amount of leaves and percentage of attached stems in the harvested fruit. No deleterious effects on yield or quality of the final processed product was seen. FDA approval of this use of Ethrel is pending.

Grapes

Mechanical harvesting of Concord grapes in Michigan surged from 1 percent of the crop in 1968 to 65 percent in 1970. In 1970, Michigan State and its Agricultural Engineering group asked Dr. Whittenberger to evaluate in terms of processed product quality several proposed methods for handling the fruit between vineyard and processing plant. Five methods differing in efficiency, cost, and manpower requirements were evaluated. Because no practical way could be devised to segregate batches in the processing plant, samples were removed to represent various stages of handling for the methods studied. In addition, studies were made of effects on juice quality of controlled preprocessing storage of grapes with differing degrees of bruise damage. Faced with the need for a rapid field method of making grape juice that would give product quality similar to that obtained commercially, Dr. Whittenberger devised a small-scale procedure with the help of three processors. A pectin-digesting enzyme was added to 500 grams of grapes, after which the grapes were converted to a slurry in a slow-speed blendor, without admixture of air. After heating to 138° F., they were allowed to stand 40 minutes and the juice was expressed through two layers of cheesecloth in a kitchen ricer; the cake was then hand-kneaded at the end. After it was weighed, the juice was heated to 188° F., bottled, cooled, and stored at 38° F. for 100 days.

Taste-panel judgments were made on color, flavor, and commercial acceptability by six officials from four grape-juice processing companies. It was found that when the grapes were processed within eight hours, each of the bulk-handling methods led to a good quality juice; therefore the economic factors could be the basis of choosing a handling method.

Pears

The last fruit work I will mention is a contract on pears under which work was carried out at Rutgers, with Dr. Claude Hills as our subject-matter specialist. Under this contract, we provided funds for evaluating the processing quality of promising selections from the Rutgers collection of pear varieties.

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*Amchem Products Inc., Ambler, Pa.

Some urgency was present in this work since the space occupied by the pear collection was required for other purposes. Emphasis was placed on selections potentially resistant to fire blight. Work was carried out in the Departments of Horticulture, Forestry, and Food Science. The project was successful in that 110 new pear selections, with some degree of resistance to fire blight, were evaluated. Forty of these were tested for two seasons. Of these, 18 were considered suitable for processed use, as judged by organoleptic evaluation and by the efficiency of thermoprocessing in preventing microbial, enzymatic, and nonenzymatic changes detrimental to consumer acceptability. Additional promising varieties for puree and low-calorie pack were identified. In addition to organoleptic testing, pH, titratable acidity, soluble solids, and ascorbic acid were determined, as well as presence and characteristics of stone cells.

Maturity of the fruit before harvest was judged by firmness, size, and skin color; Ballauf pressure readings were recorded; and fruit was stored at 30°-32° F. and after-ripened at 68°-70° F., monitored by Ballauf pressure readings.

Potatoes

Several lines of work related to processing quality of white potatoes are underway in the Plant Products Laboratory. Two are inhouse projects and the third is carried out at our Red River Valley field station in East Grand Forks, Minn.

Frozen french-fried potatoes are the largest single processed potato product, with an annual value of more than one billion dollars. In spite of this tremendous product volume, problems do exist in evaluation, control, and improvement of texture of the final end-product, as well as in prediction of texture from quality of the raw material.

There has been underway in our laboratory for a number of years a basic examination of the potential use of objective texture evaluation to measure quality of reheated (or refried) frozen french-fried potatoes. In addition, a search is underway for an objective means of relating end-product quality to the characteristics of the raw tuber.

Progress has been made in identifying and controlling the many variables which have been found to affect shear-press curves on processed product and raw materials. I will not go into detail about this work except to say that an empirical, standardized procedure has been developed for storage, selection, preparation, frying, freezing and frozen storage of the french-fry cuts, as well as for the reprocessing and shear-force testing of the product. Some of the variables affecting the results are specific gravity; size; response to storage of given time, temperature, and nature; time and temperature of blanch and of frying; type of fat; type of frier; agitation; method and time and temperature of freezing; method of reprocessing (oven or frying); and cooling after reprocessing. The effects of each of these variables have been examined during the development of the testing procedure.

Efforts to develop a test on the raw product that will predict the final processed product quality are also being made. A study, using the Durometer, was made of the interrelationships among tuber firmness, specific gravity, solids content, and test location within the tuber. Those wishing more information on progress of this work should contact Dr. W. L. Porter or Mr. L. Ross, of this laboratory.

Another continuing line of work related to processing quality of potatoes is being done at the Red River Valley Potato Processing Laboratory, which is a cooperative operation involving this Division, the North Dakota and Minnesota Agricultural Experiment Stations, and the Red River Valley Potato Growers Association. It was established about six years ago to study the effects of various source factors on the processing quality of potatoes grown in that area, and to evaluate new varieties for processing quality. The longest-running cooperative work is one we are undertaking with Dr. Florian Lauer of the Minnesota Station. Dr. Lauer is attempting to breed a potato that will fry to light-colored chips when taken directly from cold (40° F.) storage, without any reconditioning.

Roy Shaw, head of the laboratory, had an automatic chip frier made to his specifications that would slice and fry potatoes one at a time in such a manner that the results are reproducible and closely related to results obtained from the large-scale machine. A purpose for this "Red River Valley Standard Chip Cooker" was to evaluate commercial lots of potatoes and eliminate disagreements between buyer and seller of potatoes for chipping.

This equipment has proved to be extremely useful in evaluating the seedlings from Dr. Lauer's breeding work. When samples are extremely limited, one-half tuber can be tested and the other half planted. As can be seen from table 1, large numbers of samples have been tested. It can be seen that the

TABLE 1.--Summary of potato breeding program for chipping directly from 40° F. storage

Year	Number of seedlings tested	Acceptable	Percent	Borderline
1964	180	7	3.9	
1965	No report available			
1966	281	11	3.9	
1967	660			
1968	1226	35	2.84	
1969	1988+	94	4.75	130
1970	2593+	1064	41	234

results for 1970 showed a real breakthrough in that 41 percent of the seedlings made acceptable light-colored chips directly from 40° storage. Forty-five hundred samples are scheduled for chip testing this winter. I understand that at least 10 years of additional work will be required to develop a variety with the needed horticultural characteristics.

The recent development of a potato of superior processing potential and its subsequent recall due to excessively high levels of solanine illustrate another area of our research on factors related to processing quality. As our portion of a coordinated research program on this alkaloid in potatoes, we are working to improve the accuracy and reduce the time needed for analysis of tubers for solanine. Additionally we are preparing gram quantities of purified solanine to be distributed to laboratories working on this problem and used as a primary analytical standard. Further information on the solanine work can be obtained from Dr. Porter or Dr. Eugene Talley.

Another line of work in processed potato product quality is the research of Dr. Gerald Sapers, of this laboratory, on improving the flavor and stability of potato flakes. While flavor stability is adequate for commercial purposes, it is apparent that product quality does at times suffer from improper or excessive commercial storage and from the use of lower-grade raw stock than recommended by the discoverers of the process. Dr. Sapers is evaluating potato flakes that have been subjected to a variety of abuses in their experimental preparation and processing. He is determining the effect of these abuses on product quality by means of head-space analysis of the containers by gas-liquid chromatography. Those wishing more information on this work can talk with Dr. Sapers.

The Engineering and Development Laboratory of our Division is engaged in research on new products and processes. In this research vegetable and fruit varieties are almost invariably used from which processors are already making similar products. We assume that these processors are the people most likely to adopt new ideas, and that they have already determined the best varieties available in their processing areas.

As an example, companies making dehydrated potato products will have chosen varieties (1) available for the longest possible processing season, (2) having the highest dry-matter content, (3) having smooth skins and shallow eyes, and (4) capable of conditioning. The first three of these attributes affect cost: the longer the processing season the lower the capital and operating costs per pound of product; the higher the dry-matter content, and the lower the peeling and trimming losses, the higher the yield. Low sugar content in dehydrated potato products generally means better shelf life, particularly at higher temperatures, since sugars are involved in certain browning reactions resulting in "off" flavors.

Thus, we would start with certain main crop varieties having these attributes--for example, Russet Burbank (Northwest), Kennebec (East Coast), and Cobbler and Red Pontiac (Red River Valley). These are not the only varieties tested; processors and growers in other regions may become interested and request information on varieties in their areas. For example, in cooperation with the Virginia State Department of Agriculture, the Virginia Truck

Experiment Station and interested growers, we tested a "Summer" variety, Pungo, and found it to be suitable as dug in our explosion-puffing process. Unfortunately, during cold storage it accumulates excessive amounts of sugars which cannot be reduced by warmer storage, as can the best processing potatoes.

Processors of other vegetables, onions and bell peppers for instance, have developed their own varieties to suit their particular processing needs. In cooperation with these groups, we are able to obtain and test raw materials otherwise unavailable to us. One example is peppers with thick flesh which yield more uniform pieces and which retain color. Another is high-solids onions which are easier to peel and trim and have thicker rings that yield more uniform pieces with greater pungency.

On occasion, working with experiment stations and horticulturists, we test varieties not yet commercially grown but having interesting possibilities. Dr. Peterson, of the University of Wisconsin, learning of our research on explosion puffing of carrots, supplied us with three new hybrid varieties--Hybrid Gold, Spartan Bonus, and Royal Chantenay. These were bred in an attempt to get higher dry matter content and more uniform color in the phloem and the xylem than is found in the commercial processing varieties--Red Core Chantenay and Imperator. We were able to report to Dr. Peterson that one of these, Spartan Bonus, was superior in the qualities he sought.

INSTITUTE OF FOOD SCIENCE AND MARKETING —A NEW APPROACH

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Food science is rapidly becoming one of the most important and popular sciences at the university level due to increased demand for students with a food science background. Just a few years ago, the need in the food field was for students with a production and marketing background. However, times have changed with the rapidly growing popularity for convenience foods. The emphasis today is on training technically-oriented food scientists.

Not too many years ago, every housewife was really a food scientist. She purchased raw food products and prepared them for the family, and if she made a mistake, it did not influence too many people. Thus the loss was not great. Today, housewives are demanding more and more of their food at least partially prepared and, in many cases, fully prepared. With the increase in convenience foods, the industry's need for food scientists becomes greater every year.

With the development of this new era, the image of the food science field is changing. It is no longer associated with "recipe-making and cookery" but rather it revolves around the chemistry, microbiology, and processing of food and food constituents.

Since food science is relatively new, many changes had to be made at Cornell to make room for this new science. Like most universities, the various departments in the College of Agriculture and Life Sciences are commodity-oriented. For example, we have departments such as Poultry Science, Vegetable Crops, Animal Science, and so forth. Within each department, there are nutritionists, physiologists, geneticists, and more recently, food scientists. In 1966, the Dean of the College of Agriculture and Life Sciences at Cornell University appointed a study committee made up of college personnel and industry people to study food science at Cornell and make recommendations for changes. One recommendation that was considered by this committee was that all food scientists in the various commodity departments be pulled into one department, thus establishing one single strong food science unit. This was complicated, however, by the fact that at Cornell University there is a separate Food Science Department located at the New York State Agricultural Experiment Station in Geneva, N. Y. Politically and otherwise, it was not possible to place the departmental members at Geneva into one unit on the Ithaca campus. It was decided to form an Institute of Food Science and Marketing.

Institute of Food Science and Marketing

On February 1, 1970, the New York State College of Agriculture and Life Sciences at Cornell initiated the Institute of Food Science and Marketing. The purpose of the Institute is to coordinate all the activities at the university concerning the food field.

Many departments in the College of Agriculture and Life Sciences are represented. The Department of Food Science, located in Stocking Hall on the Cornell campus and formerly the Dairy Industry Department, conducts the major portion of the research and instruction on the Ithaca campus. A second department is located at Geneva, N. Y., at the New York State Agricultural Experiment Station. This facility is one of the most modern and best equipped structures in the country. In addition, there are food scientists in several of the commodity departments such as Animal Science, Poultry Science, and Vegetable Crops.

Food marketing at Cornell is also a very important component of the Institute. Interest in this area is promoted by 12 food-marketing professors who play an important role in the food field.

The Institute is also involved in teaching, research, and extension activities in other colleges at the University, including the College of Human Ecology, the Graduate School of Nutrition, the School of Hotel Administration, and the College of Chemical Engineering. The Institute provides a means for communication, participation, and cooperation for everyone concerned with food science at Cornell University.

What Has the Institute of Food Science and Marketing Accomplished?

In the less than two years that the Institute has been operating, we have been working together to strengthen food science at Cornell University. One of the early decisions was to appoint an Advisory Council consisting of 23 members to represent all phases of the food field. The Advisory Council meets twice each year and advises us on what we should be doing in food science.

Teaching. About one year ago a Curriculum Committee was appointed by the Director to develop a completely new curriculum for food science. The committee is made up of members from all segments of the Institute of Food Science and Marketing. Several new courses have been added to the curriculum and more will be added in the future. We are now teaching several courses that were formerly taught in other departments, and these courses more adequately fit the needs of our students in food science.

Research. By having an institute, it is entirely possible to have team work in the area of research. One area, for example, is that of human nutrition and food science. A group of researchers has been chosen who are working together to develop research in this area. We also include marketing people on the committee. We have several proposals of research that involve both human nutritionists and food scientists and we think we are making progress. In the future, we plan to have food scientists and human nutritionists work much closer than they have in the past.

Extension. When we started the Institute, we realized that we had not done as good a job for the food industry in the past as we should have. In some commodities, a great deal of work was done, but in other areas, we were weak. For example, we have done very little for such industries as the beer, candy, baking, and soft drink industries. We are making a great attempt to work with all phases of the food industry. Already we have workshops for industries that we have not worked with in the past.

Correspondence Courses. One way in which we think we can help industry is by the use of correspondence or home-study courses. Our Institute Advisory Council has recommended strongly that we get into this area. We plan to get started February 1, and our first course will be on "Quality Assurance." We have already selected a textbook and we are presently working on a study guide. We plan to do extensive work in the correspondence-course field.

Foundation at Cornell University Research Park. Our Advisory Council felt we could also help industry by making possible a foundation to be located at Cornell University Research Park, which is near Cornell University. At this facility, many types of quality assurance and research development work can be done that cannot be done at the university. We are actively working on this program, and we hope to be in operation in the near future. The areas suggested for Research Park are: (a) toxicology studies, (b) microbiological studies, (c) analytical analysis, (d) nutritional studies, (e) marketing studies, and (f) product development.

Student Programs. We are spending a great deal of time at the Institute trying to improve both the quality and quantity of our students. At the undergraduate level, we need much improvement. At the present time, we have 40 students, but we should have many more than this. We published a brochure entitled "Food Science at Cornell," which has been sent to all guidance counselors in the State. This has already paid dividends because many of the high school students did not know about food science at the university level, and they confused it with home economics. We have also worked closely with freshmen in the College of Agriculture and Life Sciences who have not picked an area of specialization. We hope to improve both the number and quality of our undergraduates in the near future.

Graduate Program in Food Science. In contrast to the undergraduate program, we have expanded rapidly in the number of graduate students in food science at Cornell. This fall we have 30 new graduate students, making a grand total of 70.

Recently, the Graduate Field of Food Science and Technology established six areas of concentration for graduate students including (a) Food Science

(General), (b) Food Chemistry, (c) Food Microbiology, (d) Dairy Science, (e) Water and Waste Water Microbiology, and (f) International Food Development. Graduate students now have the opportunity to specialize in any one of these areas of food science and to work with qualified professors in their chosen area of concentration.

Master of Food Science (Engineers). Starting this semester, a Master of Food Science (MFS) degree for engineers is being offered by the Graduate Field of Food Science and Technology. In the past, for example, chemical engineers have been employed by the food industry without any background in food science. The MFS degree offers the opportunity for engineers to get an excellent background in food science and thus be of more value to the food industry. The MFS degree is a professional degree and differs from the Master of Science (MS) degree in that a thesis is not required. A special problem is required, however, which allows a student to gain experience in a food laboratory.

In summary, it can be said that one way of combining the efforts of food science at a university is by the use of an Institute of Food Science. So far, we are happy with this arrangement.

QUALITY IN THERMALLY PROCESSED FOOD

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Quality in thermally processed food is a good example of the complicated interplay of many complex factors. It is not my intention today to discuss the details of improvement in quality that can be accomplished--for example, in nutrient retention or in organoleptic properties or even in economic aspects--by modifications of process technology or supply of raw material. I would prefer to discuss the potential for improvement which, in my opinion, can be attributed to changes in three major areas--namely, horticulture, processing, and packaging.

The horticultural aspects of canned foods go back to the plant and animal breeders and geneticists who have developed varieties and species adapted particularly to processing. This, of course, also involves the important additional characteristics of yield, disease resistance, flavor, texture, color, appearance, and all the other characteristics considered by the geneticist. This concept, which is becoming even more important as the ratio of processed food to "raw" food increases, is also tied into the economy of production, involving the use of fertilizers, agricultural pesticide chemicals and, even more important, mechanization.

Mechanization, while included under the umbrella of horticultural practices, is very important for maintenance of quality in processed foods. It is safe to say that any fruit or vegetable that cannot be mechanically harvested will probably not be available for thermal processing. Horticultural crops produced in bulk will be mechanically harvested. Today, 98 percent of the tomatoes for processing in California are mechanically harvested (7), as are 75 percent of the Concord grapes in the Chautauqua-Erie area (1). In some cases--for example, apples, blueberries, peaches, etc.--the quality of the available raw product may be lower than that picked by hand. This necessitates the development of handling techniques to upgrade quality, the cost of which may be offset by the reduced cost of the mechanically harvested product. The problem of quality of the bulk product in the case of Concord grape juice has been solved in admirable fashion. This industry combined the advantages of mechanical harvesting with that of bulk storage to produce a biologically stable product for future processing. The raw grapes, harvested either mechanically or by hand, are crushed, destemmed, heated to approximately 60° C., and treated with a depectinizing enzyme for 30-40 minutes to disintegrate the pulp and release the juice. The juice is separated from the skin and seeds in a continuous press and partially clarified to remove gross insoluble solids. It is then flash-pasteurized, cooled, and pumped into sterile storage tanks as large as 320,000 gallons. The bulk juice maintains its good flavor and quality for a year or more and may be further processed at leisure.

The idea of producing a biologically stable product in high volume during the relatively short harvesting season is a fascinating one. It has received a good deal of attention in the tomato industry (5), where the economic incentives for this type of approach are very attractive. Developments in California and Illinois are illustrated by the work of Nelson and coworkers. They have designed a unit to combine mechanically harvested tomatoes with bulk storage of a sterile product. Raw tomatoes are chopped, passed through a 3/8-inch screen, cooled to 40° F., and then heated to 197° F. The product is then deaerated, heated to 250° F., for 0.7 minute, cooled to 93° F. and then to 70° F. The prior cooling to 40° F. is included because it produces a desirable gain in viscosity. Each heating and cooling stage is accomplished in a heat exchanger with three concentric tubes for efficient heat regeneration. The cooled product is then pumped into a sterile tank for storage.

In 1970, a tank of 1,000-gallon capacity was investigated, with plans for industry installation in 1971. In terms of economic operation of a harvesting schedule, the advantages inherent in rapid processing of the raw product for future final processing are very attractive. There is also the possibility of establishing satellite processing stations in the actual growing area, giving the advantages of more efficient waste disposal to control pollution and lower labor and transportation costs. Together, these improvements could represent a very important advance in food processing.

The apparent economic advantages for a processing system for tomatoes such as this are sufficient to ensure that the research required for it will be done well. The system will have its effects on the quality of the final products. Since the tomatoes are mechanically harvested, some use will have to be made of those that are less than grade A in color. Some of the red-orange or pink tomatoes might be included in the blend when their color values in bulk storage are known. But the green ones cannot be used and the development of a market for these would be very desirable.

The concept of mechanical harvesting plus bulk storage of a stable intermediate for final processing is, of course, well known. One or the other concept, or both, have been used for many years for peas, fresh olives, cucumbers, strawberries, cherries, peaches, apricots, apples, orange juice, etc. Pearl (6) speaks encouragingly of the possibility in California of mechanically harvesting boysenberries, a very perishable crop, followed by immediate cryogenic freezing. Undoubtedly there will be many more applications. However, the quality of the final processed product will be no better than the quality of the intermediate product.

The processing of canned foods is changing slowly but constantly toward continuous rather than batch retorting. This involves development of equipment such as agitating cookers, hydrostatic continuous cookers, and aseptic processing lines. In my opinion, the latter probably will be the most important development because of their influence in upgrading quality and possibilities for continuous production. The improvement in quality possible by the optimization of heat treatment in an aseptic processing line is reason enough to pursue the complex development required. It is a complicated process and at present is confined primarily to packaging in tin cans because of the thermal stress involved in the container. At present, there are operating in the United States approximately 120 aseptic food packaging lines. All but one of these are for tin cans; however, considerable interest in aseptic glass lines is evident, so this ratio may change rapidly in the future.

Considerable research has been devoted to simplification of the mathematical processes for calculation of F values (2). When this is combined with simple manual or computerized calculations for microbial survival, nutrient retention, or enzyme destruction over the entire contents of a container, we have the elements required to upgrade the quality of a product. Whether the theoretical concepts involved in calculation of nutrient retention or organoleptic quality with the newer iso-j calculations will result in actual changes in process requirements remains to be seen. Present process requirements are based essentially on microbiological considerations. In view of the present climate in the FDA and the National Canners Association as regards process values, a good case would have to be made for reduction of F values based on organoleptic considerations. This may be the understatement of the year. The use of computerized process calculation, which lends itself to continuous summation of process values, has been suggested as a means of upgrading product quality. But this is also subject to these same constraints on process reduction.

Another approach to process requirements that may be promising involves a biochemical understanding of the reasons why some types of food require a longer process than others. This may include the organic acid profiles (3) produced on heat treatment, as well as the actual pH values encountered during processing at elevated temperatures. More important, this will entail more research into the biochemical factors involved in microbiological growth. There is much to be done in this area, and a better understanding will contribute to the production of high-quality canned foods.

There are many possibilities for improving the quality of canned foods, but we probably should not lose sight of ultimate consumer acceptability. If we presented to the general public the results of the recent Fort Lewis study (4) on food acceptability by military personnel, the advisability of research to improve the quality of some canned items would be questioned. For example, canned figs and canned plums were so low on the acceptability scale that they should never be served in a military dining hall. This statement may arouse indignant responses from gourmets who may rightfully complain of the lack of originality in some parts of the American diet. Nevertheless, the consumer acceptability concept is not lost on the large volume producers of canned goods. In spite of this, I sincerely hope there will always be room for quality improvement, even with obscure specialty items.

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EFFECTS OF STORAGE CONDITIONS ON PROCESSED FOOD QUALITY

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Dr. Maclinn:

The United States food industry is a $120 billion business, and it is expected to be $200 billion in 10 years (4). It supplies food to 206 million people, and it is estimated there will be some 230 million in 10 years.

Big business? Yes, big enough to be the target of professional critics who are self-claimed consumer advocates and so big that many consumers feel it is impervious to their wants and wishes.

It is at the check-out counter that the impact of inflation strikes the consumer, and this frustration leads to suspicions and criticisms of the food industry and its supplies. The food industry does have faults, but it is learning and improving all of the time. It is a young industry in comparison to the length of time people have been feeding themselves. Commercially canned and refrigerated foods came in at the beginning of the 20th century, retail frozen foods in the thirties, and low-moisture, instant foods more recently. Unfortunately, faults frequently are corrected only after laws are passed. This may happen in the case of the weakest link of the food industry's marketing channel--storage and distribution. As Brennan (2) points out, "Traditional existing Federal food laws regulate only the food manufacturers. To assure wholesome food quality, these laws should be extended to include food retailers (i.e., warehousing, transportation, and distribution)."

The study by Brennan and others was made for the New Jersey Department of Health to determine if food dating might be applicable to maintaining food quality and reducing health hazards for the benefit of consumers. The results indicated that an expiration date for foods to be removed from the shelf because of loss of quality is not an assurance until an abuse-free storage and distribution system is in practice.

There are several "codes," or recommendations, for handling foods that have been promulgated by industry associations but without power of enforcement. These codes are generalizations made on scientific data; but to date, specific data are not available on the time and temperature relationships that will best retain the quality, nutritional value, and safety of foods.

Cecil and Woodroof (3) and Ball *et al*. (1) have made extensive studies on quality and nutritional stability of canned foods at various temperatures. Van Arsdel and Guadagni (5) made a study of the time-temperature tolerance of frozen foods where temperature histories were known. From these data, research is in progress to develop mathematical models to establish specific guidelines for maximum retention of food quality and nutritional value in the marketing channels. Dr. Kan-ichi Hayakawa, research project leader, will describe the research and the progress made.

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Dr. Hayakawa:

Processed foods may be evaluated in terms of various qualities--e.g., biological, biochemical, microbial, nutritional, physical, and overall organoleptic qualities. The commercial values of processed foods have been frequently determined through the evaluation of their overall organoleptic qualities. Therefore, mathematical procedures for predicting the overall organoleptic quality of food will be presented together with other related subjects.

There are several factors which influence the rate of loss in food quality. Some of these are: biochemical and microbial reactions, moisture loss or gain, storage time, food temperature, and food variety. Among these, the last three factors are the most important. The others are dependent on time and temperature, and their influence on food quality can be estimated from the time-temperature relationships of food. Therefore, in the following discussions the prediction of time and temperature relationships during storage or handling operations will be presented, together with the above stated mathematical procedure.

Refrigerated food. Most fresh foods are subjected to cooling processes after they are harvested in order to minimize the loss of food quality. A parameter was introduced (5) to evaluate mathematically the influence of these processes on food quality. This parameter was named as a quality destruction value (QDV) and can be calculated as follows:

$$QDV = \int_0^{t_g} 10^{\frac{\mathrm{Log}_{10} Q_{10}}{18} (T - T_r)} dt \qquad (1)^{1/}$$

The QDV represents the integrated influence of a cooling process on food quality. It is more exactly defined as the duration of a hypothetical storage during which food temperature is kept at a reference temperature, T_r. According to the definition of this parameter, the loss of food quality at the end of this hypothetical storage is approximately equal to one at the end of an actual cooling treatment.

A new procedure was developed for calculating QDV's by applying eq. 1 (5). This procedure may be used when a temperature history curve of food obtained during a cooling treatment is plotted on semilog paper and when this curve is approximated with a set of linear line segments.

This procedure does not provide means for predicting temperature history curves. Therefore, experimental formulas were developed for calculating food temperatures during cooling at a constant temperature (3, 4). These formulas are given below:

a. Food temperature when $0 \leq t \leq t_l$.

i. $0.045 \leq j < 0.4$

$$\left.\begin{aligned} \Delta T &= \Delta T_o \cdot 10^{-(t/B)^{1/n}} \\ t_l &= 0.3f \\ n &= (0.3 - \log_{10} j)/0.3 \\ B &= 0.3f\,(0.3 - \log_{10} j)^{-n} \end{aligned}\right\} \qquad (2)$$

ii. $0.4 \leq j < 1$:

$$\left.\begin{aligned} \Delta T &= \Delta T_o^{\cot(Bt + \pi/4)} \\ t_l &= 0.9f(1-j) \\ B &= \frac{1}{t_l}\left[\arctan\left\{\frac{\log_{10} \Delta T_o}{\log_{10}(j\,\Delta T_o) - t_l/f}\right\} - \pi/4\right] \end{aligned}\right\} \qquad (3)$$

1/ All symbols used are defined in nomenclature at the end of this paper.

iii. $j = 1$:

$$t_l = 0$$

iv. $1 < j \leq 3$:

$$\left.\begin{aligned} \Delta T &= \Delta T_o^{\cos(Bt)} \\ t_l &= 0.7f(j-1) \end{aligned}\right\} \quad (4)$$

$$B = \frac{1}{t_l} \arccos \left[\frac{\log_{10}(j\ \Delta T_o) - t_l/f}{\log_{10} \Delta T_o}\right]$$

b. Food temperature when $t \geq t_l$

$$\Delta T = j\ \Delta T_o \cdot 10^{-t/f}$$

Food temperatures can be calculated more accurately using the above equations when they are compared with those estimated by other published formulas. This was verified through heat transfer experimentation using various fresh fruits.

During many storage or handling treatments, refrigerated food is subjected to time variable ambient temperatures. A procedure was developed for predicting food temperatures during these treatments (4). The developed procedure will be very useful for predicting food quality during storage when it is utilized together with eq. 1.

When temperature distributions in food during handling treatments are not uniform, quality losses at different locations in the food will vary. In this case, a mass average quality loss should be calculated for the reliable evaluation of these treatments. A new method was developed for making this evaluation (6).

Frozen food. There are several formulas available for predicting the temperature of frozen food during a freezing or defrosting treatment. Most of these formulas were derived by assuming that freezing or thawing occurs at one single temperature. This assumption is obviously incorrect. Therefore, a series of theoretical formulas was developed for estimating food temperatures during freezing or thawing which occurs over a relatively wide range of temperatures (1, 2). These formulas were examined for their reliability through extensive heat transfer experimentation. This examination revealed that temperatures predicted by the derived formulas agree fairly well with experimental temperatures. However, further refinements of some formulas are suggested for more accurate prediction of food temperatures, since an empirical relationship was utilized to simplify the derivations.

The quality changes during repeated freezing or thawing of foods have received a wide attention in the literature. Since there were no published data on these changes for grapefruit concentrate, an investigation was conducted (1) on this product, which was packed in 6-ounce composite cans and then exposed to alternate freezing-thawing treatments. Each freezing and thawing treatment terminated when temperatures at the centers of the cans reached -15 ± 1 and 40 ± 1 (°F.) respectively. Freezing and thawing cycles were repeated 11 times. Data obtained reveal that there are no statistically significant changes in the following factors: ascorbic acid, turbidity, viscosity, and organoleptic quality.

Canned food. It has been known that the quality of canned food deteriorates at accelerated rates when it is stored at high temperatures. Some canned foods are stored temporarily in a noninsulated warehouse immediately after their production, and if the temperatures of these foods are high when they are transferred to this warehouse, as is frequently observed in commercial canning, the foods are cooled very slowly to their ambient temperatures. In order to develop a procedure for predicting loss in food quality during this slow cooling, a theoretical formula was derived to estimate transient temperature distributions in canned foods stored in a noninsulated warehouse (7). For this derivation, it was assumed that a geometrical configuration for the pile of canned foods was an infinite slab and that ambient temperatures varied sinusoidally during storage. According to heat transfer experiments conducted in one commercial warehouse during a summer season, there is fair agreement between experimental temperatures and those estimated by the derived formula. It would be worthwhile to state that a theoretical formula for estimating temperature in a rectangular parallele-piped body can be easily obtained from the formula by using the multiplication theorem for heat conduction.

There are many published articles containing the rates of quality loss in canned foods subjected to various storage temperatures. However, published data are not readily available on quality loss of canned apple slices, peas, asparagus, and corn. Therefore, loss rates for these products were determined by using a flavor panel (7). Storage temperatures selected were 100°, 70°, 40°, 35°, and -20° F., and flavor was evaluated at 0, 1, 2, 4, 9, and 15 months of storage. Statistical analyses of organoleptic data showed that the 100° F. storage temperature resulted in a considerable loss of quality before one year's storage, while at a storage temperature of 70° F., the loss of quality became apparent only at the end of the year's storage. It was also observed that storage at 35°, 40°, or -15° F. did not result in a very severe loss of quality.

Work in progress and work planned. The quality of dehydrated food is greatly affected by its moisture and temperature. Therefore, an investigation has been initiated to develop a new mathematical method for predicting these two physical factors when food is stored in time-variable ambient temperatures and in time-variable relative humidity. An investigation for developing moisture transfer potentials in dehydrated foods has also been initiated to simplify calculations involved in the evaluation of moisture sorption in food.

Most frozen foods are subjected to time-variable ambient temperatures while in storage and marketing channels. Therefore, an investigation is in the planning stage to develop a mathematical method for predicting transient temperature distributions in frozen foods while in these channels.

Conclusion. We believe that our investigations will provide tools that will be very useful for evaluating various handling treatments, thus ensuring maximum nutrient and quality retention in food.

Nomenclature

B	Constant evaluated eq. 2, 3, or 4 (dimensionless).
f	Slope index of cooling curve (time).
j	Intercept coefficient of cooling curve (dimensionless).
n	Constant evaluated by eq. 2 (dimensionless).
Q_{10}	Temperature coefficient for quality loss reaction which can be evaluated from shelf lives at various storage temperatures (dimensionless).
QDV	Quality destruction value (time).
T	Food temperature (temp.).
T_a	Ambient temperature (tem.).
T_r	Reference temperature (temp.).
T_o	Initial temperature of food (temp.).
t	Cooling or treatment time (time).
t_g	End of cooling or treatment (time).
t_l	Constant Evaluated by eq. 2, 3, or 4 (time).
ΔT	$T_a - T$ when $T_a > T$ or $T - T_a$ when $T_a < T$ (temp. difference).
ΔT_o	$T_a - T_o$ when $T_a > T_o$ or $T_o - T_a$ when $T_a < T$ (temp. difference).

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CAN CENTRALIZED MEAT PROCESSING PROVIDE PRODUCT QUALITY AND STABILITY AS WELL AS ECONOMY?

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First of all I want to say that I am not an expert in the area of centralized meat processing. I believe that there exists several relatively knowledgeable people in this area today; however, most of them are employed with the commercial companies who appear to be leaders in this endeavor, but until now have been more concerned with the economics rather than the quality aspects of centralized processing. Secondly, I want to say that I believe that centralized meat processing is the coming method for meat merchandising, be it fresh or frozen, in saw-ready primals or subprimals, or in ready-to-purchase retail packs. There is absolutely no doubt in my mind that because of the necessity for control over the variables normally encountered in meat merchandising--size and shape of cuts, retail cut yield, shrink, fat trim, lean to fat ratio, package weight, sanitation, etc.--more and more centralized meat processing will appeal to retailers as the method by which quantity and quality control can be most satisfactorily achieved. This applies particularly to the larger chains, who are currently merchandising the bulk of the total meat sold at retail.

During the last five to ten years, there has been considerable discussion of centralized meat processing at many different levels. I personally have aided in the arrangements to have some aspect of this topic discussed at the Meat Packers and Processors conferences that have been held annually in Pennsylvania (1, 6, 7).

According to James S. Toothman (8), of the Penn State staff, during the 1960's, supermarkets were able to achieve only minor real gains in labor and space productivity (as reported by the Supermarket Institute). Wage and salary costs now represent substantially more than half of their total operating costs. Central cutting and packaging is viewed as the most promising possibility for reducing meat retailing costs even though only one chain in Pennsylvania is known to have actually begun work on a plant for centralized processing.

From the title of this paper, "Can Centralized Meat Processing Provide Product Quality and Stability as Well as Economy?" one might assume that the possibilities of economies from centralized meat processing are well established (9). I know of no marketing specialist who has shown that centralized meat processing will not be more economical than current operations at point of sale. I suppose the main concern at this time must then be, "can centralized meat processing provide product quality and stability?"

If we consider first of all the products available today, we see that currently some meats appear to be better suited to the requirements of centralized processing than their predecessors, and some appear to be less desirable from this standpoint. In order to attain the goals of more automation, more uniform quality, and more efficient operations by the use of centralized processing, we must of necessity have large quantities of relatively uniform raw materials. From the standpoint of beef, the situation looks good. During the last 25 years, the number of beef vs. dairy cattle has changed from about a 1:1 to a 4:1 ratio. The percentage of fed cattle has more than doubled--from 33 to 70 percent--and the percentage of cattle currently graded U.S. Choice has increased from 28 to 56 percent. All of these factors point to a more uniform, higher quality beef picture, or the kind necessary to fit best into a closely controlled, centralized beef-processing program.

However, we must consider that more of the beef is being produced in the Western States, far from Eastern markets. In July, 46 percent of all cattle on feed were in the Western States, compared with 41 percent last year, and 35 percent 5 years ago. In the future, we will have to plan on longer hauls to get this more uniform beef to the East.

On the other hand, some of the happenings associated with current pork production tend to magnify the problems of centralized meat processing. The pale, soft, and exudative (PSE) state of many of the pork carcasses--particularly the lean, larger muscled ones--because of their lower water-binding ability, produces packages in which the pork cuts literally swim. Sleeth (7) has reported that drip is the major reason why fresh meat needs to be rewrapped. It is quite obvious, therefore, that these particular cuts should be wrapped as close to the point of purchase as possible. Packers today believe that the PSE condition is correlated with reduced fat content and increased muscularity; hence this problem is definitely on the increase. This is the reverse of the situation with beef, where it appears that modern production procedures are such that centralized meat processing is favored. When comparing these two meats, the sole point in pork's favor is that only about one-fifth of the total pork consumed enters into the retail trade in the fresh state, where PSE is of significance.

If we consider meat quality from the standpoint of a product that most closely approaches the initial fresh condition, we must of necessity consider all aspects of handling, from the carcass on the kill floor to the individually packaged item for retail sale. In an interesting paper, John Bard (2) points out that, as reported by Haines and Smith in 1933, the control of surface contamination of fresh meats is the most important factor determining their shelf life. Table 1 lists Haines and Smith's results obtained in studies with lean beef at various levels of contamination with storage at 0° C. (32° F.). Similar results have been reported on studies involving fresh, processed, and prepackaged meats at storage temperatures ranging from 32° to 50° F.

Bard also concluded that even with the development of hermetically sealed vacuum packages that prevent the growth of molds, shelf life is still dependent upon the initial bacterial contamination level. Once contamination at any level has taken place, storage temperature becomes the major factor of importance in determining shelf life (see table 2).

TABLE 1.--Effect of initial contamination on the storage life of lean beef

Initial bacterial count (organisms per square centimeter)	No. of days at 32° F. before slime development
100,000	8
10,000	10
1,000	13
100	15
10	18

TABLE 2.--Effect of storage temperature on the shelf life of meats

Storage temperature (° F.)	No. of days before slime development
32	10
34	7
37	4
41	3
50	2
61	1

Bard also reviewed the American Meat Institute report summarizing the importance of storage temperature as follows: "Under practical conditions, a product will keep at least twice as long when held at 32° F. as will the same product with a similar level of contamination at 40° F. It will keep at least four times as long at 32° F. as at 50° F."

Naumann, Stringer, and Gould (5), of the Missouri Station, point out that initially the tissues of live animals and their resultant carcasses are practically free of microbes. It is during subsequent handling and processing that the contamination that determines shelf life occurs. The microbes affecting shelf life of meats grow at refrigeration temperatures. Work recently reported by Carroll (3) in an Irish publication indicates that control over temperature and bacterial contamination resulted in prepacked beef that lost oxymyoglobin (red color) at only about one-fifth the rate found under current commercial conditions.

Mr. Seth Shaw (6) has concluded that it has been necessary to cut and package meats near the point of sale because of the extreme perishability of the product, that the only two ways to extend the short marketing life of fresh meat are again simply to prevent or minimize contamination and then to hold the temperature so low that the microorganisms will not grow or multiply.

Nauman, Stringer, and Gould (5) state in their excellent publication, "Guidelines for Handling Prepackaged Meat in Retail Stores," that increased shelf life is a necessary product requirement for centralized packaging of meat. A summary of their recommendations would include:

1. Maintain the best possible sanitation procedures for facilities and equipment.

2. Keep the initial contamination of carcasses and wholesale and retail cuts to a minimum (ante mortem washing).

3. Maintain low temperatures throughout all cutting, processing, packaging, and storing procedures.

4. Pretrim whole and subprimal cuts to reduce levels of surface contamination prior to cutting.

5. Use the correct wrapping materials that will permit oxygen penetration to maintain the color of fresh meats but be water impermeable to prevent dehydration.

We should consider some relative comments by Seth Shaw (6) who reports that currently all major food chains and many other handlers and users of meats are employing some aspects of centralized meat processing. Most noteworthy has been the handling of luncheon meats. Interim programs of marketing fresh meats, particularly beef, involve the breaking of carcasses into trimmed primals and subprimals. Monforts, Missouri Beef Packers, and Iowa Beef Packers appear to have successful and extensive programs in this area. Many of these cuts are vacuum packaged, boxed, and palletized for delivery from packing plants and warehouses to the stores. The film protects the cuts from contamination and dehydration. If the fresh meat processed in this way has been sanitarily handled before packaging with the temperature held below 32° F., it can be kept at least three weeks and still have excellent case life after the final cutting and packaging at the store level. One system used in this manner is Cryovac, which is reported to add one cent per pound to processing costs. Probably the most significant result of this packaging technique is reduced shrink and, under certain conditions, the cost of the wrap may exceed the cost of the shrink. Here I believe we would have to conclude that more research is needed in the area of packaging.

I have been informed that Liberal Markets in Ohio, who have about 40 to 50 stores to service, went fully to centralized cutting and packaging in August 1970. It is my understanding that Liberal has a closed-door policy and will share no information nor conduct tours of their operation.

Because of the inherent problems associated with fresh-meat handling, and because lower temperatures usually mean longer shelf life, the building of a centralized meat-processing system utilizing frozen cuts has had continous appeal. Most of us have heard by now that members of the Kansas State University faculty have just about completed an extensive study in which they attempted to establish a system for centralized meat processing (4). The approach in this case was to utilize a new film produced by the DuPont Company and to attempt again to establish a workable merchandising scheme for prepackaged frozen meats. In the past, wraps that have been used have usually been clear which soon produced an unattractive package because of ice crystal formation or cut discoloration. Also, commercial attempts to merchandise frozen cuts of meat wrapped in aluminum foil or other opaque material have not been successful. Consumers want to see what they are buying. The DuPont development is described as a skin-tight wrap that is perfectly clear. The cut of meat may be frozen and then wrapped, or wrapped and then frozen. Considering that air is evacuated from the package, the former was reported as the desired procedure by the Kansas workers. Although the final report covering this project is not yet published, some of the findings have been reported at the 1971 Reciprocal Meats Conference held last June, and also at the Food Distribution Research Society meetings held only last week.

The Kansas workers report that in their extensive test-marketing research, the skin-tight DuPont film was successful. They believe that to be commercially feasible, a more rapid packaging machine must be forthcoming. This is currently being developed by DuPont and Cryovac. They also feel that the frozen product they merchandized was of the highest nutritional value and that color or bloom retention is currently their biggest problem. They point out that meat pigment, or myoglobin content, varies with the species (beef, lamb, and pork) and that there is muscle variation and within-muscle variation. Thus the oxygen demand for maintaining a bright and attractive color varies considerably, almost from package to package. Because of these variations in the meat, the following conditions should vary in order to obtain best results:

1. Fabrication conditions such as cutting-room temperatures and bloom time, which may be specie specific.

2. Packaging - DuPont skin-tight film is oxygen permeable and designed to maintain frozen meat color.

3. Freezing - Slow freezing may result in a dark color while rapid freezing sets the bloom but may produce a faded product.

4. Storage - The Kansas workers recognize variations in storage limitations and report that the maximum storage time is not known; however, they did maintain some cuts in a satisfactory condition for six months.

Another important variable noted by them was the interrelated aspects of temperature and lighting in the retail case. They recommend maintaining an ambient air temperature in the retail case of -20° F. or lower. They report that case loading and automatic defrosting are serious problems and that when frozen meat once loses its attractive color it is impossible to retrieve it. (At the same meeting, Art Perez, of Tyler Refrigeration, reported that with fresh meats, the effects of automatic defrosting in a correctly tuned system are negligible.) Light sources and intensities of light in meat cases, shown by studies at the Kansas Station to vary tremendously, affect the stability of frozen meat color. Incandescent light masked color discoloration; 75-, 100-, and 150-foot candles (ft.-c.) raised the surface temperature of displayed cuts 2° to 6° F., and 300 ft.-c. elevated surface temperature 12° F. Obviously these are significant factors relative to shelf life.

From the standpoint of a merchandising system and from the extensive random consumer interviews that were carried out during this study, the following were concluded:

1. There was probably no flavor difference between the fresh and frozen products.

2. The frozen product wrapped in skin-tight film was rated better than the home frozen. (It should be considered here that surveys have shown that when meat purchased as fresh is not eaten at the next meal, consumers will freeze it, usually under conditions less than desirable.)

3. There was no overall consumer dislike of the frozen product. In one test store, the frozen test items made up 19.2 percent of total meat sales, while at another location this amounted to 15.6 percent. These figures were maintained throughout the 14-week test period.

4. Frozen meats as tested appeared to be best adaptable to both convenience type stores and the larger chains. Three companies are currently producing the frozen product for sale. Costs for skin-tight merchandising have been calculated to be between 16 and 18 cents per pound for total processing from carcass to retail package. Packers have deemed this an insane figure--both too low and too high. Figures comparing costs of fresh versus frozen-cut packages are not available.

In conclusion, the Kansas study illustrates that consumer resistance to frozen meats can be reduced. These workers do not use the term "eliminated" when discussing consumer resistance to frozen meats. Therefore, I have concluded that this is still a significant factor and may be the biggest deterrent to the initiation of a centralized meat-processing system involving frozen cuts.

My own conclusion to the question posed by the title of this paper is yes. Sufficient is known about the initial condition of the product; the control of contamination; temperature and humidity regulation during production, shipment, and storage; and the development of packaging materials, methods, and machines to provide the industry with the necessary meat-processing system. The as yet unexplained reluctance to fully launch centralized meat-processing operations is noticeably apparent. Packers, distributors, and retailers all seem to be waiting for someone to establish the successful system that they may then adopt as their model. I suppose it will be up to the appropriate governmental agencies to produce this desired model.

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RECOGNIZING FRESH MEAT QUALITY

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The meat research program of the Market Quality Research Division (MQRD) includes studies for the development of improved procedures for identifying wholesomeness in meat inspection and quality in meat grading. The program is also concerned with the maintenance and improvement of meat quality while the meat is in marketing channels. This morning we shall limit our discussion to MQRD research on recognizing fresh meat quality in meat grading.

Commercial Grading for Quality

When we speak of recognizing fresh meat quality, we are describing an attempt to predict palatability and end-use suitability of the meat in question. Such factors as tenderness, flavor, juiciness, and eye appeal come to the mind of the consumer; whereas fat content, shelf life, binding capacity, and color are of added importance to the further processor. Tenderness has long been considered one of the most important quality attributes sought in meat. Yet the best methods for shear-force measurements of cooked meat, when compared to taste panel evaluation, seldom yield a correlation better than $r = 0.85$, and if they do, then one of the evaluations is usually suspect. Attempts to relate raw-meat to cooked-meat quality are even more difficult. The best practical procedure developed thus far is the USDA grading system.

The standards for grades have evolved through identification of traits that can be correlated to particular quality attributes. For example, meat from a physiologically mature animal is more likely to be tough than meat from a young animal. This difference can be due to additional cross linkages of collagen bonds, to increases in muscle-fiber diameter, or even to a decrease in enzymatic activity in more mature animals (2). Thus, in grading a carcass, the degree of bone ossification, the amount of myoglobin in the *Longissimus dorsi*, and the texture of the muscle all can be used to aid in characterizing the animal's maturity and, concomitantly, the tenderness of its meat. The amount of marbling has been shown to be a good index of juiciness in meat and undoubtedly aids in flavor enrichment and enhancement. Thus, by putting these and other parameters together, we have the basic guidelines for selecting meat according to its quality.

Keeping Grade Standards Current

In order to keep pace with changes in meat production and marketing practices, in-house and cooperative research with State experiment stations is being carried out to provide data on palatability and acceptability of meat resulting from such changes. For a number of years, the British breeds of beef cattle, such as Angus, Hereford, and Shorthorn, have predominated as the sources of beef. Over these same years it has been recognized that wide variations exist within each breed with respect to body size and muscle development. Scientists at the University of Wisconsin, under cooperative agreement with MQRD, have segregated cattle on the basis of body sizes, using a hedonic scale of 0 to 7. Twenty Angus and 20 Hereford calves were found to fill each of the body sizes from 1 to 5, and 20 Carolais cattle were found for the body sizes 3 to 7. Data from this study are presently being analyzed to relate the influence of the differences in body size to feed efficiency, carcass quality, and meat palatability.

Some segments of the beef industry have shown an interest in Angus and Hereford crosses with exotic and dairy breeds such as Simmental, Limousin, South Devon, Holstein, and Brown Swiss. This interest is partially due to the aversion of the consumer to purchase waste fat, the potential of more rapid weight gains, and the advent of yield grading. Yield grading is the procedure used by USDA graders to identify the muscle-to-fat ratio in beef carcasses. Yield grade 1 is associated with lean carcasses, whereas yield grade 5 represents carcasses having much fat. Researchers at the U. S. Meat Animal Research Center at Clay Center, Nebr., are involved in a study to determine variation in muscling of the live animals and carcasses from the beforementioned British and exotic or dairy crosses. Kansas State University is cooperating in the study with MQRD by obtaining complete cut-out and palatability data on these carcasses. This study should allow the Department to evaluate the yield grade standards over a wide range of differences in muscling and fatness.

Another production practice being evaluated from the standpoint of meat quality is the feeding of bulls to obtain a carcass with minimum waste fat. Researchers at the University of Nebraska, in cooperation with MQRD, have evaluated carcasses from bulls and steers at 9, 12, 15, 18, and 24 months of age. They reported that young bulls have a higher feed conversion and yield carcasses with a larger lean content than steers of the same age. In the first year of the study at Nebraska, the mean percent separable lean of the 9-10-11 rib of bulls was reported by Wise *et al*. (8) to be about 6.6 percent greater than the lean content of steers. These researchers further showed that by varying the feeding regime, bull carcasses exhibiting the same carcass grade characteristics as steers can be produced. Arthaud *et al*. (1) reported that meat from bulls was significantly tougher than meat from steers. However, the magnitude of this difference, when evaluated by a taste panel, was less than 1.5 on a 10-point hedonic scale. The panel found steer meat to be juicier than bull meat, but the difference was less than 1 point on a 10-point hedonic scale. Steers, when compared to bulls, had a significantly more pronounced flavor of only 0.5 in a hedonic scale of 1 to 5. Additional data (as yet unpublished), representing a second year of testing, include physical, chemical, histological, and palatability evaluations to determine whether differences attributable to sex can be detected.

Objective Test for Fresh Meat Quality

To be accepted by the meat industry, an objective test for meat quality would have to be as rapid and precise as the present grading system, which it would replace. In an attempt to identify chemical, physical, and histological changes that can be developed into rapid indices of physiological maturity, 9 Angus steers were slaughtered in each age group of 6, 12, 18, 24, 36, 48, 60, and 72 months; and carcasses were evaluated. Five muscles--the *Longissimus dorsi*, *Psoas major*, *Semimembranosus*, *Semitendinosus*, and the *Biceps femoris*--were cooked to an end-point temperature and evaluated by taste-panel evaluation and shear-force determination. Sarcomere length was measured as an index of rigor. Muscle-fiber diameter was found to increase with animal maturity. The muscles were also evaluated for changes in amino acid content, free fatty acids, triglyceride fatty acids, phospholipids, glycerol, cholesterol, and mineral content. Data from these evaluations are still being analyzed.

One of the physical approaches tried in this study was reported by Davis *et al*. (*4*). It involves sending an ultrasonic pulse through the right metacarpal of a slaughtered steer and determining either the resonant frequency parameter or the velocity of the sound wave passing through the bone. Bones from 34 steers approximately 6, 12, 18, 24, and 30 months of age were evaluated by this procedure. The simple correlation between days of age of the animals and the resonant frequency parameter was r = 0.88. The correlation between animal age and the ultrasonic velocity was r = 0.87. This procedure is based on the principle of measuring the degree of ossification of the bone as an index of maturity from which tenderness could then be estimated, as done in the present grading system. The procedure must still be modified so that it can be used effectively in commercial coolers (on bones attached to the carcass) before it can gain much acceptance.

Because it is being used commercially, one procedure worth mentioning at this point is the Armour Tenderometer. MQRD had no part in its development or in the research evaluating its effectiveness. Carcasses are segregated and marketed as Tender Tested Beef on the basis of the force required for penetration of ten needles into the *Longissimus dorsi* of a hanging carcass. Carpenter *et al*. (*3*) evaluated 228 beef carcasses using the tenderometer and found significant correlations between that measurement and the shear values and panel-tenderness ratings of the cooked meat. Marbling inhibits needle penetration, thus increasing the tenderometer reading so that fat meat might test tougher than it actually is. Martin *et al*. (*5*) showed that marbling had a significant effect on tenderometer readings and developed an equation that can be used to compensate for this effect of marbling.

Quality Factors Not Presently Measured

Admittedly, some quality variables that affect the consumer's acceptance of meat are not determined by the grading or inspection procedures presently available to the meat industry. I would like to mention six.

1. The present system segregates a complete carcass into a particular category. However, some muscles within the carcass are more tender than others, and this is reflected in the retail price and end-use suitability of each muscle. Also, a particular muscle from a high-grade carcass should possess quality attributes that are better than those of the corresponding muscle from the lower-grade carcass. The present grading system does not, however, take into account the fact that the muscles of the round and ribeye may be made more tender in relation to other muscles of the carcass. This can be done during chilling by using the Texas A&M "Tenderstretch" system of suspending the carcass from the aitch bone rather than from the Achilles tendon. Orts et al. (6) demonstrated that such suspension to stretch muscles before rigor inhibits the shortening of sarcomeres, a condition that is associated with toughening of meat during rigor.

2. At present, there are no known rapid objective tests that are economically feasible to measure changes in quality that occur during the post mortem aging process. One must presume that each beef carcass will receive at least one week of aging while it is traveling through the marketing channels. This period is long enough to ensure that an unfrozen carcass has passed through rigor and has undergone some increased tenderness from enzymatic action. Although they are not directly reflected in the meat grade, any increases in tenderness obtained by the Kroger Tender Ray Process; Swift's Proten papain procedure; the controlled atmosphere, high-temperature aging procedure recently developed in Finland; or conventional aging for extended periods should increase the value of the meat to the buyer.

3. During the last several years consumers have voiced an aversion to excess fat in meat. Yield grades identify differences in lean and fat content, but are of little direct benefit to the consumer because carcasses are trimmed during the preparation of retail cuts. Thus the lean-to-fat ratio is changed during marketing.

4. At least one European country is considering adding collagen content to their criteria of grade standards, especially for canned and further-processed meat items. Researchers at Lublin, Poland, in cooperation with MQRD, are determining the composition of seven muscles from cattle, swine, sheep, and chickens of varying maturity, sex, and state of nutrition. It is recognized that collagen is not as digestible as fibrillar or sarcoplasmic protein and can exceed 5 percent in some beef muscles. Therefore, in geriatrics and pediatrics, where food intake is carefully controlled, a beef patty cooked rare might supply much less than the anticipated protein requirement. At present, chemical methods for determining collagen are so time consuming that it would not be economically feasible to evaluate the muscle groups of each carcass on this basis. Results on distribution of collagen within muscles have not yet been published. Prost et al. (7) showed, however, that (a) individual bovine muscles within a carcass differed only in fat and moisture content but not in level of protein, and (b) although intramuscular fat increased and moisture decreased with age, protein level remained fairly constant.

5. Meat from the muscles of slaughtered animals varies in other aspects besides collagen content. Scientists at the Oklahoma State University,

in cooperation with MQRD, are involved in exploratory research to develop handling procedures for individual bovine muscles that are boned from hot carcasses. They will try to maintain the beef tenderness, juiciness, flavor, and yield that would result from chilled carcasses. In conjunction with this research, the scientists will try to identify criteria in the hot carcass or the individual muscles which correlate favorably with quality attributes of the cooked meat.

6. One remaining factor regarding recognition of fresh-meat quality, but which is not actually part of the grading structure, is the microbiological condition of the carcasses and retail cuts. When spoilage organisms reach the level of 10^6 or 10^7 per cm^2, fresh meat becomes noticeably discolored and odoriferous, making it unsalable; it is then excluded from the marketing channels. A procedure for rapidly screening carcasses at a packing plant for microorganisms approaching these levels would have a definite beneficial effect on meat quality. Since biochemical testing is so time consuming, Dr. P. Vincent, of our Meat Investigations, is evaluating the possibility of using pyrolysis liquid-gas chromatography for identification and enumeration of microorganisms of particular importance to the meat industry and the consumer. Thus far he has differentiated among members of the *Aspergillus glaucus* and *A. flavus* groups using the pyrolysis technique.

Summary

The meat research program of the Market Quality Research Division, Agricultural Research Service, USDA, includes studies for the development of improved procedures for identifying the quality attributes of fresh meat. In commercial channels, recognition of meat tenderness, juiciness, flavor, and aroma begins with evaluation of the live animal and continues with a subjective evaluation of the carcass. Meat quality of individual muscles is not evaluated separately but is based on carcass quality evaluation. The U. S. Department of Agriculture's subjective grading system is the best procedure presently available. It is being continuously reviewed and it is revised whenever necessary to keep pace with changes in meat production and marketing practices. In-house studies in cooperation with State experiment stations are being carried out to provide data on palatability and acceptability of meat resulting from such changes.

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